TELLUS INSTITUTE
Resource and Environmental Strategies

GLOBAL RESOURCE CONSERVATION BENEFITS ASSOCIATED WITH WASTE DIVERSION IN IOWA

Submitted to:

The Iowa Department of Natural Resources (DNR)
Waste Management Assistance Division

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February 2000

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Printed on recycled paper

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EXECUTIVE SUMMARY

This report presents the results of a unique effort to quantify and account for benefits of waste diversion that are often overlooked in local benefit-cost analyses. In recent years, a great deal of research has addressed whether local diversion programs—including source reduction, recycling and composting programs—are cost effective. These studies have generally produced mixed results. The most successful diversion programs, including many with the highest diversion rates, are cost-effective while other diversion programs hover at or slightly below the break-even point (virtually all diversion programs are profitable when recycled commodity values are high as they were in 1995). While such studies provide important insight for enhancing performance, operation, and cost-effectiveness of local diversion programs, their "bottom line" focus often does not account for the substantial upstream benefits of diversion which occur beyond the community's border. These benefits, referred to as "Resource Conservation Benefits" (RCBs), are the focus of this report.

As previous research and common sense suggests, all integrated waste management options incur some level of costs at the local level, but for the most part,[1] only diversion options incur "upstream" resource conservation benefits which are lost when materials are disposed. This study tries to capture and quantify the latter and makes no attempt to quantify local costs of diversion.[2] RCBs associated with waste diversion often occur well beyond the boundaries of local waste systems in global material consumption, production, and/or natural resource extraction processes. RCBs addressed in this report fall into four broad categories discussed in more detail below: economic and employment benefits, land-use benefits, energy benefits, and air and water pollution benefits. To the extent possible, this report identifies and quantifies RCBs within each of these broad categories based on Iowa diversion information and published research. Care is taken to ensure that only those benefits that are quantifiable, based on reasonably documented and published information, are accounted for. Thus, the benefits quantified are generally conservative and should be viewed as "lower bound" estimates.

The point of departure for the analysis is Iowa diversion information, which consists of annual tonnage and material composition data for source reduction (SR), recycling, and composting activities occurring throughout the state in 1995 (the most recent year for which complete data was available). RCBs are calculated on a material by material basis for each of the three types of diversion (SR, recycling, composting) using standard "multipliers" developed or compiled by Tellus for this effort based on published data and limited primary research. The RCB multipliers are compiled in a basic spreadsheet model to facilitate future use by other interested organizations in Iowa, and development of alternative scenarios and assumptions.

Results of the RCB analysis for Iowa's 1995 diversion and achievement of the 50% diversion goals are summarized in Table ES-1. In 1995 Iowans diverted one ton of material for every two tons of waste they disposed, resulting in a 33.5% statewide diversion rate equivalent

[1] Exceptions could include, for example, methane recovery in landfills.
[2] Additionally, note that no effort was made to account natural resource subsidy impacts or distribution effects of benefits.

to approximately 1.3 million tons annually. If Iowa achieves its 50% diversion goal this value will increase to approximately 1.9 million tons annually.

Economic benefits attributed to Iowa diversion based on available quantitative information include recycled material or compost commodity value; purchase costs for finished goods avoided through more efficient material use resulting from source reduction; avoided waste management costs resulting from source reduction; and direct and indirect employment impacts related to recycling and remanufacturing industries. Most of these benefits accrue to organizations in Iowa that divert waste or use recycled materials in production processes. Total economic benefits produced by Iowa diversion (excluding employment impacts) amounted to nearly $90 million in 1995, the equivalent of nearly $80 for each household in Iowa. If the state achieves its diversion goal, this value will increase to over $100 per household. In addition, Iowa's 1995 diversion produced over 47,000 jobs, which is equivalent to about 3 percent of the State's employment.

Land-use benefits attributed to Iowa diversion include avoided disposal impacts for all diverted materials, and avoided forested acreage harvested as a result of paper diversion. Iowa diverted nearly 91 million cubic feet of materials from landfills in 1995, which will increase to 137 million cubic feet if the state achieves the 50 percent diversion goal. Diversion also reduces the need for virgin materials for which extraction or production has adverse land-use impacts. Here paper is particularly important because it is the largest component of Iowa's waste diversion. Recycled paper production requires less virgin wood pulp for paper production, and source reduction reduces the demand for paper production altogether. Iowa's 1995 diversion avoided the need to harvest trees from about 210,000 acres of forest globally, which will increase to 281,000 acres if the state achieves its diversion goal.

Energy benefits associated with diversion result primarily from reduced or avoided energy use in material production and resource extraction processes compared to production processes that rely on "virgin" (i.e., non recycled) resources. As shown in table ES-1 Iowa's 1995 diversion reduced global energy demand by approximately 11.1 million MMBTUs annually. To put this number in perspective, it would cost over $100 million to produce an equivalent amount of electricity at a cost of $0.04 per kilowatt-hour.

As with energy impacts, Iowa's 1995 diversion produced global reductions in air and water pollution. When materials are prevented or recycled, air and water emissions associated with mining and processing raw resources are avoided altogether, and in many cases production of products with recycled feedstocks can reduce air and water pollution as well. For source reduction and recycling the report quantifies reductions in six specific pollutants, all of which bear on air quality. Taken in the aggregate, air emissions avoided due to diversion amounts to approximately 31.7 pounds of the EPA's five major criteria pollutants, for each household in Iowa. Additionally, diversion avoided air emissions of 3,000 pounds of lead, a well-known poisonous substance. Reductions in greenhouse gas (GHG) emissions from diversion are also quantified, resulting in a total of nearly 1000 pounds per Iowa households in 1995. The report quantifies reductions in a range of emissions that bear on water quality for recycling only as no similar data was available for source reduction. The emission reductions shown in Table ES-1 illustrate the "mutli-media" environmental benefits associated with waste diversion.

Details on the data and procedures used to develop the information in Table ES-1 are provided in the accompanying technical report and appendices.

Table ES-1. Annual Resource Conservation Benefits from Iowa Waste Diversion

RCB	1995 Diversion (33.5%)	50 Percent Diversion	Difference
Diverted Tons	1,307,220	1,948,739	641,519
Economic Benefit (dollars)	$89,510,084	$116,655,926	$27,145,842
Avoided Landfill Space (cubic feet)	90,981,741	137,067,948	46,086,207
Forest Acreage	210,997	280,658	69,660
Energy Benefits (Million BTU)	11,094,003	13,409,698	2,315,695
Avoided Air Emissions			
Carbon Monoxide (lbs)	11,806,458	15,609,107	3,802,649
Hydrocarbons (lbs)	3,096,329	4,085,694	989,366
Nitrogen Oxides (lbs)	5,281,384	7,280,340	1,998,955
Particulate Matter (lbs)	5,259,162	6,942,023	1,682,862
Sulfur Oxides (lbs)	6,275,524	8,761,030	2,485,506
Lead (lbs)	2,763	3,641	877
Greenhouse Gasses (MTCE)	453,190	641,887	188,697
Avoided Water Emissions (lbs)			
BOD	239,613	315,671	76,058
COD	662,233	872,440	210,207
Suspended Solids	1,114,270	1,467,963	353,693
Dissolved Solids	2,406,823	3,170,799	763,976
Cyanide	1,694	2,231	538
Sulfuric Acid	624	822	198

1. INTRODUCTION

In 1988, the State of Iowa established a goal to reduce 1988 disposal levels by 50% by the year 2000. By 1995, the state had made substantial progress toward the goal, reducing its 1988 waste stream by 34% through source reduction, reuse, recycling, and composting activities throughout the state.

While various organizations throughout Iowa and the US have conducted extensive research on the economic costs and benefits of community waste diversion programs,[3] these studies tend to focus on the local cost of diversion compared to other waste management activities such as garbage collection and waste disposal. While such studies are important, their focus on the local "bottom line" does not capture the full benefits of waste diversion. This report attempts to capture the full benefits of diversion. Diversion produces substantial global benefits that occur beyond the boundaries of local waste management systems. Such "resource conservation benefits" (RCBs) include economic and employment benefits, land-use benefits, energy savings and emission reductions in material consumption, production and resource extraction processes.

In recent years, a wide variety of research on the economic and environmental impacts of waste diversion has been conducted by organizations throughout the US. This report uses much of this research to develop standard "multipliers" or factors that can be applied to Iowa material diversion data to quantify annual RCBs associated with Iowa's diversion. The data required for this analysis is appended in the tables provided at the end of this report, and in accompanying spreadsheets that the Division and other organizations in Iowa can use to update or change assumptions, and develop alternative projections. Note that these data only account for global RCBs, but not local costs, of diversion. To account for local diversion costs, well known techniques, such as full cost accounting and readily available local cost data, can be used in conjunction with the RCB data.

Remaining chapters in this report address four broad categories of RCBs associated with Iowa's waste diversion: economic activity, improvements in land use, reductions in energy use, and avoided air and water emissions. For each of the categories considered, RCBs associated with diversion are identified and, to the extent data permits, quantified on an annual basis based on 1995 diversion data. Note that while some of these benefits addressed accrue to Iowa organizations that divert or use diverted material (e.g., most of the economic and employment benefits), other benefits, such as land-use benefits, energy savings and pollution emission reductions, occur beyond the state's boundaries in global resource extraction and production processes. Whether benefits accrue to those within Iowa or beyond the state's boundaries, all of the benefits quantified herein result from Iowa waste diversion activities.

To make the discussion in the report more accessible, benefits are expressed in well-known units. For example, reductions in energy use, developed in millions of BTUs in the

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[3] See for example: *The Economic Impact of Recycling Study*, conducted for the Recycle Iowa program (Beck, 1997); *Iowa Statewide Compost Market Assessment*, conducted for the Iowa Department of Natural Resources (Resource Conservation and Development of Northeast Iowa, Inc., 1998); and *Using Full Cost Accounting To Enhance Integrated Waste Management Planning, Pricing, And Performance in Iowa* (Tellus, 1998).

appendices, are converted to an equivalent number of gallons of gasoline in the report. At the conclusion of the report, an alternative scenario is presented which quantifies RCBs associated with achieving the State's 50% diversion goal.

2. CHARACTERIZATION OF IOWA'S DIVERSION

Quantification of RCBs begins with data on the tonnage and composition of material diverted through source reduction, recycling, and composting in Iowa as summarized in Table 1.

The starting point for the development of Table 1 is information submitted by local solid waste planning areas in "goal status reports."[4] The goal status reports provide the total tons of waste generated and disposed in landfills in 1988 (the baseline) and 1995. The Iowa Department of Natural Resources (DNR) compiles this data to compute overall diversion progress based on the difference between 1995 and 1988 per-capita disposal rates. Based on this information, total diversion in 1995 was 1,307,220 tons or 33.5% of the Iowa waste stream. Because RCB impacts vary by the type of diversion (i.e., source reduction, recycling, composting) and material type, more detailed information on material composition of Iowa's diversion streams needed to be developed next.

The source reduction column in Table 1 accounts for the effects of improved material efficiency, lightweighting, material substitution and on-site composting. Per-capita material source reduction estimates from a study currently being conducted for the US EPA Office of Solid Waste were used to estimate Iowa source reduction composition for paper, glass, plastic metals, food, and wood.[5] Because source reduction of these materials results in large part from national and international production and consumption trends,[6] no variation from the national per-capita estimate was assumed in Iowa. On the other hand, because yard trimming source reduction is highly variable by geographic location, Iowa's yard trimming source reduction was estimated separately based on information reported in state yard trimming compost studies and disposal characterization studies. [7,8] This captures the effect of the state's yard trimming disposal ban. As shown in Table 1, Iowa's total annual source reduction in 1995 is estimated at 426,935 tons. Subtracting this value from total diversion (1,307,220 tons), leaves 880,026 tons of material that must be accounted for through other diversion activities.

The "Recovery" column in Table 1 accounts for the effects of recycling, centralized composting, and beneficial reuse diversion activities in Iowa. Recent studies provide composition data for 713,858 tons of Iowa's recovered recycling and compost streams. [9,10] The remaining 166,428 tons, accounted for in the "all other" recovery category is assumed to consist of materials such as foundry sands and other non-hazardous industrial and construction and

[4] Iowa Department of Natural Resources, *Iowa Comprehensive Planning Areas' 1995 Goal Progress Status*, April 29, 1999.
[5] Tellus Institute, *National Source Reduction Report* (Draft, 1999). Prepared for the United States Environmental Protection Agency.
[6] Note, for example, that the value for plastics is negative to account for growth in this material stream resulting from material substitution for glass.
[7] R.W. Beck. *Iowa Solid Waste Characterization Study* 1998. Prepared for Iowa Department of Natural Resources.
[8] Resource Conservation and Development of Northeast Iowa, Inc. *Iowa Statewide Compost Market Assessment* (1998). Prepared for Iowa Department of Natural Resources. Page 18.
[9] R.W. Beck. *Economic Benefits of Recycling* (1997). Prepared for RecycleIowa.
[10] Resource Conservation and Development of Northeast Iowa, Inc. *Op. Cit.* (1998).

demolition materials which is diverted for beneficial reuse by some local planning areas. Source reduction and recovery tonnage is added in the column labeled "diversion" in Table 1.

Disposal tonnage composition is based on a recent statewide landfill composition analysis.[11] Material in this category consists of both standard municipal solid waste, and other non-hazardous and construction and demolition materials disposed in Iowa landfills. Adding diversion tonnage and disposal tonnage yields "generation" by material. Material diversion tonnage is divided by material generation tonnage to compute the diversion rate by material shown in the final column of Table 1. Table A-1 and the accompanying notes in the Appendix provide additional details on Iowa diversion and disposal tonnage in 1995.

Table 1: Iowa Diversion and Waste Disposal Tonnage, 1995

Material	Source Reduction	Recovery	Diversion	Disposal	Generation	Material Diversion Rate
	Tons	Tons	Tons	Tons	Tons	Percent
Paper	49,533	367,175	416,708	668,286	1,084,994	38.4%
Plastics	(2,814)	23,423	20,609	293,994	314,603	6.6%
Glass	25,829	28,908	54,737	44,034	98,772	55.4%
Metals	27,692	141,321	169,013	128,218	297,231	56.9%
Yard Waste	277,858	113,858	391,716	33,673	425,389	92.1%
Food Waste	18,503	NA	18,503	191,679	210,182	8.8%
Wood	30,334	39,173	69,507	243,484	312,992	22.2%
All Other	NA	166,428	166,428	986,888	1,153,316	14.4%
Total	**426,935**	**880,286**	**1,307,220**	**2,590,257**	**3,897,478**	**33.5%**

[11] R.W. Beck. *Iowa Solid Waste Characterization Study* 1998. Prepared for Iowa Department of Natural Resources.

3. Annual Economic Benefits from Diversion

Diversion changes a burden—waste to be managed—into a source of economic value and a basis for employment. This section defines and quantifies these two general categories of economic benefits on an annual basis based on Iowa's 1995 diversion data shown in Table 1 and Table A-1.

3.1 Economic Value of Diversion

For the purposes of quantifying economic value of Iowa's 1995 waste diversion, the following benefits are considered:

- Recycled or composted commodity value based on current (1999) economic markets for recovered materials;
- Avoided purchase costs based on current (1999) purchase prices for finished goods diverted through source reduction;
- Avoided waste management costs for materials source reduced based on the sum of variable garbage collection cost and average tip fees.[12,13,14]

For the first two categories of economic value, per-ton values were compiled by material type for SR, composting, and recycling. Applying these per-ton values to the product- and material-specific tonnages diverted (shown in Table A-1) produces the first two components of economic value shown in Table 2. The final component of value shown in Table 2 was computed by multiplying total source reduced tonnage (426,935 tons) by the sum of variable collection cost per ton ($26.40) and average tip fees per ton disposed ($32.50).

Iowa's 1995 waste diversion produces a total annual economic value of $89 million or nearly $80 for each household in Iowa. Interestingly, a commonly cited source of economic value—recovered commodity value—provides less than 20% of the value shown in Table 2. Most of the economic value comes from source reduction, which consists primarily of avoided purchases of finished goods that are far more valuable per ton than recycled materials. The value of recycled newsprint, for example, is about $45 per ton, compared to $602 per ton for each ton of finished newsprint purchased by newspaper publishers. Thus, to the extent that source reduction reduces the amount of finished goods required to produce a product (e.g., through lightweighting, material substitution, etc.), it produces substantial economic benefits on a unit basis compared to recycling.

[12] Note that no avoided waste management costs are assumed for recycling or recovery since these activities can incur collection and/or processing costs.

[13] We assume source reduction will result in avoided variable costs of collection. We assume total collection of $52.81 with variable costs representing 50% of the total. Source: Franklin Associates/Keep America Beautiful. 1994. *The Role of Recycling in Integrated Solid Waste Management to the Year 2000.* Table H-5, page H-23.

[14] An avoided tip fee of $32.50 is used for each source reduced ton based on Glenn, Jim. "The State of Garbage in America." *Biocycle.* April 1999. Page 66.

Table 2: Annual Economic Value from Iowa 1995 Diversion

Source of Value	Value Created ($ Millions)
Materials Recovered	18.1
Purchases Avoided by SR	46.3
Waste Management Costs Avoided by SR	25.1
Total	89.5

3.2 Employment Benefits from Diversion

The information presented in Table 2 does not take into account the jobs created directly by the recycling or remanufacturing[15] industries in Iowa. These impacts are provided in a study conducted for Recycle Iowa[16] and in a national study that identifies remanufacturing activity by state.[17] Data from these studies are summarized in Table 3.

Table 3: Iowa Employment Directly Related to Diversion, 1995

Industrial Activity	Direct Employment
Remanufacturing	8,400[18]
Production Using Recycled Feedstock	8,800[19]
Total	**17,200**

The direct employment shown in Table 3 has a multiplier effect, creating additional employment throughout Iowa's economy. The Recycle Iowa study shows that the economic activity including re-spending of wage income associated with 8,800 jobs directly related to recycling leads to a total of 24,100 jobs. On this basis, the 17,200 positions shown in Table 3 would lead to 47,100 positions economy wide. This simple extrapolation likely understates the total employment created because remanufacturing positions are high skill/wage jobs which typically create greater local employment than do average manufacturing positions. In 1996 Iowa employment was about 1.6 million in total.[20] Thus, the 47,100 positions amount to about 3 percent of the state's employment.

15 Remanufacturing is one form of reuse, a type of source reduction. Remanufacturing is the only type of source reduction for which employment impacts are readily available.

16 R.W. Beck. *Op. Cit.* (1997). Prepared for Recycle Iowa.

17 Lund, Robert T., 1996. *The Remanufacturing Industry: Hidden Giant*. Boston University, Boston, MA January.

18 According to page 13 of Robert Lund's *The Remanufacturing Industry: Hidden Giant*, 174 of the 9903 remanufacturing firms or 1.76% in the United States are in Iowa. Also according to Lund, there is 480,000 direct employment from remanufacturing. Taking 1.76% of this yields 8,400 direct employment in Iowa due to remanufacturing.

19 R.W. Beck. *Op. Cit.* (1997). Prepared for RecycleIowa. Page 4-12.

20 U.S. Department of Commerce. *Statistical Abstract of the United States, 1998.* Table number 649.

4. Land Use Benefits from Diversion

Diversion of waste has a number of beneficial effects related to land use, including:

- Reduced demand for and conservation of existing landfill space;
- Avoided land impacts associated with harvesting or resource extraction resulting from increased use of recycled commodities in place of virgin materials in production processes.

Another major land use benefit associated with Iowa's diversion is land application of finished compost, a major component of Iowa's diversion stream. Compost is used as a soil amendment in horticultural and agricultural applications, increasing organic matter in the soil and reducing the need for synthetic fertilizers. While this benefit is likely to be significant in Iowa, no published information was available to quantify it and thus, it is not accounted for in the RCB land use calculations.

4.1 Landfill Space Impacts

Diverting waste reduces landfill space requirements for waste disposal. Table A-3 in the Appendix quantifies this effect. The results indicate that 67 million cubic feet of landfill airspace were saved through recovery, and 24 million cubic feet were saved by source reduction, for a total of 91 million cubic feet. This amounts to about 84 cubic feet per Iowa household. Diversion from landfilling is particularly important because, as shown in Table A-3, about 67 percent of the waste diverted is organic. Organic waste disposed in modern landfills contributes to generation of methane and leachate.[21] Release of methane can cause odors and, in high enough concentrations, explosions (methane is also a greenhouse gas addressed in Section 6). Leachate discharges pose a threat to groundwater supplies. Modern landfills are designed to avoid releases, but no containment or management systems are perfect. Diversion of organic waste provides a preventative approach for reducing landfill methane and leachate production.

4.2 Land Impacts Associated with Resource Extraction

Diversion also reduces the need for virgin materials for which extraction or production has adverse land-use impacts. Here paper is particularly important. As shown in Table 1, paper represents the largest component of Iowa's diversion, accounting for more than one-third of the total. Recycled paper production requires less virgin wood pulp for paper production and source reduction reduces paper production impacts altogether. A recent EPA study showed that diversion of paper waste results in net gains in forested areas.[22] Table A-4 and Table A-5 quantify the additional forest acreage which would need to be harvested absent Iowa's diversion. The calculation shows that Iowa's diversion avoids the need to harvest trees from about 210,000 acres of forest.

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[21] Kreith, Frank, 1994. *Handbook of Solid Waste Management.* McGraw-Hill, Inc., page 12.7.

[22] U.S. EPA, 1998. *Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste*. September.

Paper is not the only material from which diversion has clear, upstream land use benefits. Iron and steel provide another example. As shown in Table A-1, Iowa diverts about 157,000 tons of steel cans and ferrous scrap from disposal. Use of this material in place of iron ore avoids the substantial land use impacts associated with mining. While mining need not have adverse land use impacts, in some cases it currently does.[23] Reprocessing recovered steel involves the use of substantial amounts of electricity. However, use of recovered steel consumes half the energy of steel made from virgin materials.[24] Thus, energy use reductions may be the source of further beneficial land use impacts. One could make similar arguments for other recovered materials: use of recovered glass avoids the mineral extraction required for virgin product, use of recovered plastic reduces the demand for fossil fuel, reducing both its extraction and the occasional spills associated with its large-scale marine transport.

[23] Winfield, Mark S., 1999. "Waste Prevention and the Front-End of the Materials Cycle: Perspectives from Canada," presented at *OECD Workshop: Extended Producer Responsibility and Waste Minimisation Policy in Support of Environmental Sustainability*. May 4-7, Paris.
[24] Wernick, Iddo K. and N.J. Themelis, 1998. "Recycling Metals for the Environment," *Annual Review Energy Environment*. 23:465-97.

5. ENERGY SAVINGS FROM DIVERSION

The energy required to produce paper, plastics, glass and metal from virgin feedstocks generally is greater than the energy required to produce them from recycled materials. Energy used to extract and produce materials is avoided altogether through source reduction. When these impacts are considered in conjunction with waste management and recycling system energy requirements, diversion often produce net energy savings.

Energy savings were estimated using data from a recent EPA report[25], which provides life-cycle energy requirements for products, produced from both virgin and recycled materials. Using this data, energy savings were calculated for each material diverted on a per-ton-recycled or source-reduced basis. These per-ton values and the tons of each material recycled or source reduced were used to calculate the total energy savings. The detailed calculation is shown in Table A-6 in the Appendix. A summary of the results is provided in Table 4 below. There the energy savings have been converted from millions of BTUs, a standard energy unit, to equivalent gallons of gasoline, a more familiar unit. There are about 1.6 million automobiles registered in Iowa, and the average automobile gets 21.3 miles to the gallon.[26] Thus, the energy saved by Iowa's waste diversion is enough for about 1,185 miles of travel for each and every car in the state.

Table 4: Energy Savings from Iowa's 1995 Diversion

(Millions of Gallons of Gasoline[27])

Source Reduction	16
Recycling	73
Total	**89**

Energy use is an essential aspect of modern life. However, using energy as efficiently as possible is important for a variety of reasons. Energy is expensive. For example, even at current "low" prices gasoline costs over $1 per gallon. Further, energy use, particularly for transportation and the production of electricity, is also a major source of adverse environmental impacts. Diversion provides an important opportunity to improve the efficiency of energy use without curtailing the services a modern society requires.

[25] U.S. EPA, 1998. *Op. Cit.* September.

[26] U.S. Department of Commerce, Bureau of the Census, 1998. *Statistical Abstract of the United States – 1998.* 118th Edition.

[27] Assumes 125 MMBTU per gallon of gasoline.

6. Avoided Air and Water Emissions from Diversion

Waste diversion leads directly to reductions in harmful air and water emissions. For source reduction and recycling this report quantifies reductions in six specific pollutants, all of which bear on air quality. The report also quantifies reductions in greenhouse gas (GHG) emissions, an area of growing concern. For recycling, reductions in a range of emissions that bear on water quality, are also quantified, however no similar data was available for source reduction. While the results presented do not capture all of the avoided emissions due to waste diversion, they are sufficient to support this section's key point: Iowa's waste diversion provides clear, quantifiable and substantial environmental benefits.

6.1 Avoided Air Emissions

The avoided air emissions shown in Table 5 were estimated based on the best published aggregate data for source reduction and recycling.[28] The estimates are shown in Table A-7 of the Appendix. Table A-8 presents the avoided air emissions due to energy savings associated with source reduction. Because the source reduction values exclude direct production process emissions, this approach provides a conservative estimate of the emissions avoided due to Iowa's recycling.[29] Taken in the aggregate, the data in Table 5 show that the air emissions avoided due to diversion are substantial. Diversion amounts to approximately 31.7 pounds of the EPA's five major criteria pollutants, for each household in Iowa. Additionally, Table 5 shows that 1995 diversion avoided air emissions of 3,000 pounds of lead, a well-known poisonous substance.

Iowa's waste diversion also reduces the emissions of carbon dioxide, methane and other GHGs. The results in Table A-10 show that Iowa's diversion avoids 453,190 metric tons of carbon equivalent (MTCE) of GHG emissions or nearly 1000 pounds for every household in Iowa. While acceptance of the importance of the greenhouse effect is growing, controversy does persist concerning it. With this in mind, it is important to note that waste diversion is not undertaken based on the avoided GHG emissions. Rather, waste diversion provides GHG emissions reductions as a byproduct of its operation, and so helps avoid a possible future problem.

[28] Franklin Associates, Ltd. *The Role of Recycling in Integrated Solid Waste Management to the Year 2000.* Prepared for Keep American Beautiful, Inc.

[29] See the notes accompanying Table A-8 in the appendix for additional details on the conservative nature of this analysis.

Table 5: Air Emissions Avoided by Iowa's 1995 Diversion

Pollutant	Adverse Effects[30]	Amount Avoided (pounds)
Carbon Monoxide	Is absorbed by the lungs and decreases the oxygen-carrying capacity of the bloodstream and decreases available oxygen for body tissue.	11,806,458
Hydrocarbons	Are a component of smog. They can cause eye irritation, plant injury and reduced visibility.	3,096,329
Nitrogen Oxides	Can cause respiratory disorders, reduced visibility and damage to vegetation.	5,281,384
Particulate Matter	Can cause reduced visibility, eye irritation and soiling of clothing.	5,259,162
Sulfur Oxides	Causes "acid rain" when sulfur oxides react with moisture in the air to form sulfuric acid. This acidifies lakes and streams killing fish and making the water too acidic to be reinhabited.	6,275,524
Lead	Causes human health problems including anemia and cognitive deficits.	3,000[31]

[30] Corbit, Robert A. *Standard Handbook of Environmental Engineering.* McGraw-Hill, Inc.1990. Page 4.3-4.5.
[31] The lead emissions savings do not include savings from source reduction.

6.2 Avoided Water Emissions

Waste diversion avoids a variety of adverse water emissions including suspended and dissolved solids which can cloud water, materials which through reactions remove oxygen which sustains aquatic life, and dangerous chemicals such as cyanide and sulfuric acid. Due to data limitations this report only quantifies the adverse emissions to water avoided by Iowa's recycling. The details of the quantification are presented in Table A-7 and summarized in Table 6 below. The avoided emissions of solids and oxygen-removing materials are substantial. The emissions of cyanide and sulfuric acid are much smaller. However, given the poisonous and destructive character of these substances, avoiding release of thousands of pounds of these substances is clearly significant.

Table 6: Water Emissions Avoided by Iowa's 1995 Recycling

	Adverse Effects	Savings from Recycling (in lbs.)
BOD	Biochemical oxygen demand (BOD) is a measure the total carbonaceous demand for oxygen and an indicator of the biodegradable organic material in the water. The presence of biodegradable organics can lead to the depletion of oxygen as the organics are degraded. [32]	239,600
COD	Like BOD, chemical oxygen demand (COD) is an indicator of the biodegradable organic material in the water. It is the amount of strong chemical oxidant which is reduced by the waste.[33]	662,240
Suspended Solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions.[34]	1,114,280
Dissolved Solids	Dissolved solids are the organic and inorganic molecules and ions which are present in true solution in water	2,406,820
Cyanide	Cyanide is a poison. When inhaled, ingested or absorbed through the skin it cause breathing difficulty and is explosive in larger quantities.[35]	1,700
Sulfuric Acid	Even dilute sulfuric acid can irritate skin and mucous membranes.[36]	620

[32] Corbit, Robert A. *Standard Handbook of Environmental Engineering.* McGraw-Hill, Inc.1990. Page 6.1-6.6.
[33] Corbit, Robert A. *Ibid.* McGraw-Hill, Inc.1990. Page 6.1-6.6.
[34] Corbit, Robert A. *Ibid.* McGraw-Hill, Inc.1990. Page 6.1-6.6.
[35] Information from: http://www.wt.com.au/safetyline/d_pubs/cyanide.htm
[36] Information from EPA web site: http://www.epa.gov/grtlakes/seahome/housewaste/house/sulfuric.htm

7. LOOKING AHEAD: RCBS ASSOCIATED WITH ACHIEVING 50 PERCENT DIVERSION

Preceding chapters have quantified various resource conservation benefits associated with Iowa's *1995* diversion levels of approximately 34 percent of the waste stream. The state established a goal of reducing 50 percent of the 1988 disposal rate by 2000, and the DNR's Waste Management Assistance Division is actively researching and promoting programs and strategies to achieve the goal. This section examines how RCBs associated with Iowa's 1995 diversion could change if the state were to achieve its diversion goal.

The first step in this analysis involved increasing 1995 diversion levels to achieve the 50 percent diversion goal as shown in Appendix Table A-11. This was accomplished by assuming a linear increases in source reduction and recovery of all individual materials except yard trimmings (which is already recovered at a rate of over 90%) based on the proportion of materials diverted in 1995 (see the notes to Table A-11 for additional details). Once this was accomplished, RCB factors discussed in the preceding sections and shown in the appendices were applied to the revised material diversion data to calculate the total and incremental RCBs associated with 50 percent diversion as summarized in Table 7. Note that Table 7 does not address all of the RCBs addressed in previous sections, but only those for which there are standard multipliers. For example, there is no standard multiplier for employment impacts, and therefore these are not included in the 50 percent diversion scenario.

Table 7: Resource Conservation Benefits for 1995 and 50 Percent Diversion

RCB	1995 Diversion (33.5%)	50 Percent Diversion	Difference
Diverted Tons	1,307,220	1,948,739	641,519
Economic Benefit (dollars)	$89,510,084	$116,655,926	$27,145,842
Avoided Landfill Space (cubic feet)	90,981,741	137,067,948	46,086,207
Forest Acreage	210,997	280,658	69,660
Energy Benefits (Million BTU)	11,094,003	13,409,698	2,315,695
Avoided Air Emissions			
Carbon Monoxide (lbs)	11,806,458	15,609,107	3,802,649
Hydrocarbons (lbs)	3,096,329	4,085,694	989,366
Nitrogen Oxides (lbs)	5,281,384	7,280,340	1,998,955
Particulate Matter (lbs)	5,259,162	6,942,023	1,682,862
Sulfur Oxides (lbs)	6,275,524	8,761,030	2,485,506
Lead (lbs)	2,763	3,641	877
Greenhouse Gasses (MTCE)	453,190	641,887	188,697
Avoided Water Emissions (lbs)			
BOD	239,613	315,671	76,058
COD	662,233	872,440	210,207
Suspended Solids	1,114,270	1,467,963	353,693
Dissolved Solids	2,406,823	3,170,799	763,976
Cyanide	1,694	2,231	538
Sulfuric Acid	624	822	198

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Table A-1: Details on Iowa Diversion and Waste Disposal Tonnage, 1995

	Source Reduction[1]		Recovery[2]		Disposal[3]		Diversion[4]		Generation[5]		Diversion Rate[6]
	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent
Paper	**11.6%**	**49,533**	**41.7%**	**367,175**	**25.8%**	**668,286**	**31.9%**	**416,708**	**27.8%**	**1,084,994**	**38.4%**
Newspaper	7.5%	31,952	10.0%	88,294	3.0%	77,708	9.2%	120,246	5.1%	197,953	60.7%
OCC and Kraft Bags	NA	NA	25.6%	225,047	7.1%	183,908	17.2%	225,047	10.5%	408,955	55.0%
High Grade	NA	NA	3.6%	31,699	1.8%	46,625	2.4%	31,699	2.0%	78,324	40.5%
Other	4.1%	17,581	2.5%	22,135	13.9%	360,046	3.0%	39,716	10.3%	399,762	9.9%
Plastics	**-0.7%**	**(2,814)**	**2.7%**	**23,423**	**11.4%**	**293,994**	**1.6%**	**20,609**	**8.1%**	**314,603**	**6.6%**
PET Containers	-0.5%	(2,291)	1.2%	10,307	0.3%	7,771	0.6%	8,016	0.4%	15,787	50.8%
HDPE	-0.1%	(523)	0.7%	6,286	0.7%	18,132	0.4%	5,763	0.6%	23,895	24.1%
LDPE	NA	NA	0.4%	3,442	0.0%	-	0.3%	3,442	0.1%	3,442	NA
Other	NA	NA	0.4%	3,388	10.4%	268,092	0.3%	3,388	7.1%	277,955	1.2%
Glass	**6.0%**	**25,829**	**3.3%**	**28,908**	**1.7%**	**44,034**	**4.2%**	**54,737**	**2.5%**	**98,772**	**55.4%**
Metals	**6.5%**	**27,692**	**16.1%**	**141,321**	**5.0%**	**128,218**	**12.9%**	**169,013**	**7.6%**	**297,231**	**56.9%**
Steel Cans	0.6%	2,525	3.3%	29,036	0.8%	20,722	2.4%	31,561	1.3%	52,283	60.4%
Aluminum Cans	0.5%	1,970	0.5%	3,996	0.2%	5,181	0.5%	5,966	0.3%	11,146	53.5%
Ferrous	5.4%	23,197	11.7%	102,782	3.6%	91,954	9.6%	125,979	5.6%	217,933	57.8%
Non-ferrous	NA	NA	0.6%	5,507	0.4%	10,361	0.4%	5,507	0.4%	15,868	34.7%
Yard Waste	**65.1%**	**277,858**	**12.9%**	**113,858**	**1.3%**	**33,673**	**30.0%**	**391,716**	**10.9%**	**425,389**	**92.1%**
Food Waste	**4.3%**	**18,503**	**NA**	**NA**	**7.4%**	**191,679**	**1.4%**	**18,503**	**5.4%**	**210,182**	**8.8%**
Wood	**7.1%**	**30,334**	**4.5%**	**39,173**	**9.4%**	**243,484**	**5.3%**	**69,507**	**8.0%**	**312,992**	**22.2%**
Other	**NA**	**NA**	**18.9%**	**166,428**	**38.1%**	**986,888**	**12.7%**	**166,428**	**29.6%**	**1,153,316**	**14.4%**
Total	**100%**	**426,935**	**100%**	**880,286**	**100%**	**2,590,257**	**100%**	**1,307,220**	**100%**	**3,897,478**	**33.5%**

Notes to Table A-1

1. Source Reduction is calculated using the results of a draft Tellus study for the US EPA entitled *National Source Reduction Report* (expected publication in fall 1999). The results of the EPA study indicated that there are 6 main contributors to source reduction, ferrous metals, publications, yard waste, food waste, wood waste, and food containers. In the food container category, plastic containers are replacing metal and glass containers causing source expansion of plastic and source reduction of metal and glass. To calculate source reduction tonnage for Iowa, the per capita source reduction for the materials included in the 6 categories was calculated using the national data and multiplied by the population. For yard trimmings, source reduction was calculated by subtracting the tonnage of yard waste composted and disposed in 1996 from the total yard waste generated in 1990 (425,289 tons) as reported in the *Iowa Solid Waste Characterization Study* (Beck, 1998).

2. Recovery includes both recycling and composting. Recycling data is 1995 data from *Economic Benefits of Recycling*, Table 4-1 (Beck, 1997). Yard Waste Composting data is the 1996 value from Table 5-4 of the *Iowa Statewide Compost Market Assessment* (Resource Conservation and Development of Northeast Iowa, Inc. 1998). The tonnage listed in the other category is assumed to be industrial waste recycling. This number is calculated by subtracting the disposal, source reduction, recycling and composting tonnages from the total generation.

3. Disposal composition information is from the *Iowa Solid Waste Characterization Study*, Table 2, page 2-5. The total disposal tonnage was provided by the DNR in the *Comprehensive Planning Areas' Current Goal Progress Status* 5/28/97 spreadsheet.

4. Diversion is source reduction plus recovery.

5. Generation is source reduction plus recovery plus disposal.

6. Diversion rate equals diversion divided by generation.

Table A-2: Details on Economic Benefits from Iowa Diversion, 1995

	Recovery			Source Reduction			Total
	Tons[1]	Recovered Commodity Value per Ton[2]	Recovered Commodity Value[3]	Tons[4]	Avoided Purchase Cost per Ton[5]	Avoided Purchase Cost[6]	Economic Benefit[7]
Paper	**367,175**		**$6,956,135**	**49,533**		**$19,230,153**	**$26,186,288**
Newspaper	88,294	$45	$3,973,230	31,952	$602	$19,230,153	$23,203,383
OCC and Kraft Bags	225,047	$5	$1,125,235	NA	$600	NA	$1,125,235
High Grade	31,699	$60	$1,901,940	NA	$1,400	NA	$1,901,940
Other	22,135	$(2)	$(44,270)	17,581	NA	NA	$(44,270)
Plastics	**23,423**		**$1,865,440**	**(2,814)**	**$800**	**$(2,251,066)**	**$(385,626)**
PET Containers	10,307	$120	$1,236,840	(2,291)	NA	NA	$1,236,840
HDPE	6,286	$100	$628,600	(523)	NA	NA	$628,600
LDPE	3,442	NA	NA	NA	NA	NA	$-
Other	3,388	NA	NA	NA	NA	NA	$-
Glass	**28,908**	**$15**	**$438,438**	**25,829**	**NA**	**NA**	**$438,438**
Metals	**141,321**		**$7,018,350**	**27,692**		**$13,240,705**	**$20,259,055**
Steel Cans	29,036	$30	$871,080	2,525	$908	$2,293,604	$3,164,684
Aluminum Cans	3,996	$560	$2,237,760	1,970	$2,260	$4,452,076	$6,689,836
Ferrous	102,782	$30	$3,083,460	23,197	$280	$6,495,025	$9,578,485
Non-ferrous	5,507	$150	$826,050	NA	NA	NA	$826,050
Yard Waste	**113,858**	**$16**	**$1,821,728**	**277,858**	**$16**	**$4,445,722**	**$6,267,450**
Food Waste	**NA**	**NA**	**NA**	**18,503**	**$16**	**$296,042**	**$296,042**
Wood	**39,173**	**NA**	**NA**	**30,334**	**$373**	**$11,301,990**	**$11,301,990**
Other	**166,428**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Total	**880,286**		**$18,100,091**	**426,935**		**$46,263,546**	**$64,363,637**

Notes to Table A-2

1. Tonnage of recovered material is from Table A-1.

2. Recycling material multipliers is from *Waste News* May 24,1999. Unless otherwise noted the *Waste News* multipliers used represent the average prices recyclers pay for loose materials in Chicago for the week ending May 14. The Newspaper price represents bailed materials picked up. The non-ferrous multiplier comes from the April 26, 1999 *American Metal Markets* newspaper. The non-ferrous multiplier is the estimated dealer price of heavy soft lead in Chicago on April 23, 1999. The price of lead was chosen for the non-ferrous multiplier because lead makes up the majority of non-ferrous scrap. The composting multiplier used for the yard waste recovery comes from *Organic Materials Management Strategies* by the EPA, May 1998 page 51 Table 5-2.

3. Savings is the tons recovered multiplied by the material value.

4. Tonnage of source reduced material is from Table A-1.

5. Source reduction avoided purchasing costs were calculated individually by Tellus. The newspaper multiplier is the wholesale price of newsprint according to the Newspaper Association of America, Newsprint Transaction Prices, as report in April 1999 on www.naa.org/info/facts. The OCC multiplier is amount saved per ton source reduced by switching to reusable corrugated boxes per Tellus Resource Conservation Benefits Model created for Nebraska Department of Environmental Quality, 1999. The high grade paper multiplier is the price per ton that the consumer of high grade paper pays based on paper prices for *great White Multi-Use 20 paper,* 1999. The plastic multiplier is the whole sale price of HDPE according to the April 1999, *Plastic News*. The steel cans multiplier is the commodity price of black plate from the American Metal Markets newspaper April 26, 1999. The aluminum multiplier cans from a 1997 Tellus report to the EPA entitled *Economic and Environmental Benefits from Source Recycling and Recycling of Office Paper, Corrugated, and Aluminum Cans,* p. 3. The ferrous multiplier is the commodity price of hot rolled steel from the American Metal Markets newspaper April 26, 1999. The yard and food waste multipliers are the revenue per unit ton for yard trimmings composting from *Organic Materials Management Strategies* by the EPA, May 1998 page 51 Table 5-2. The wood waste multiplier is the average of savings from switching to multi-use pallets and switching to slipsheets per Tellus Resource Conservation Benefits Model created for Nebraska, 1999.

6. Avoided purchasing is the tons source reduced multiplied by the material value.

7. Total economic benefit is the sum of the savings from recovery and source reduction.

Table A-3: Details on Landfill Space Savings from Iowa Diversion, 1995

	Recycling			Source Reduction			Total
	Tons[1]	cubic feet per ton[2]	Savings (cubic feet)[3]	Tons[4]	cubic feet per ton[5]	Savings (cubic feet)[6]	Cubic Feet[7]
Paper	**367,175**		**32,246,280**	**49,533**		**4,179,316**	**36,425,596**
Newspaper	88,294	84	7,449,806	31,952	84	2,695,920	10,145,726
OCC and Kraft Bags	225,047	90	20,254,230	NA	90	NA	20,254,230
High Grade	31,699	84	2,674,603	NA	84	NA	2,674,603
Other	22,135	84	1,867,641	17,581	84	1,483,396	3,351,037
Plastics	**23,423**	**190**	**4,453,669**	**(2,814)**		**(535,024)**	**3,918,645**
PET Containers	10,307	190	1,959,782	(2,291)	190	(435,592)	1,524,190
HDPE	6,286	190	1,195,225	(523)	190	(99,432)	1,095,793
LDPE	3,442	190	654,465	NA	190	NA	654,465
Other	3,388	190	644,197	NA	190	NA	644,197
Glass	**28,908**	**24**	**696,889**	**25,829**	**24**	**622,669**	**1,319,559**
Metals	**141,321**		**16,967,697**	**27,692**		**3,632,300**	**20,599,996**
Steel Cans	29,036	121	3,499,875	2,525	121	304,406	3,804,281
Aluminum Cans	3,996	270	1,078,920	1,970	270	531,885	1,610,805
Ferrous Scrap	102,782	121	12,388,902	23,197	121	2,796,009	15,184,910
Non-ferrous Scrap	5,507	NA	NA	NA	NA	NA	-
Yard Waste	**113,858**	**45**	**5,123,610**	**277,858**	**45**	**12,503,594**	**17,627,204**
Food Waste	**NA**	**34**		**18,503**	**34**	**624,463**	**624,463**
Wood	**39,173**	**84**	**3,305,222**	**30,334**	**84**	**2,559,462**	**5,864,684**
Other	**159,764**	**28**	**4,417,335**	**NA**	**NA**	**NA**	**NA**
Total Organics	**520,206**		**40,675,112**	**376,227**		**19,866,836**	**60,541,948**
Total	**873,622**		**67,210,702**	**426,935**		**23,586,780**	**90,981,741**

Notes to Table A-3

1. Tonnage of recovered material comes from Table A-1.

2. Landfill space multipliers are calculated using the landfill density of each material from Table B-9 of the EPA's *Characterization of MSW in US: 1997 Update*. The other category under recovery is assumed to be mostly sand. The density of sand comes from Table 3 of the California Integrated Waste Management Board's *Conversion Factors for Individual Material Types.* It is assumed that the difference between the landfill and loose densities of sand is negligible. The density was converted to the units of cubic feet per ton and divided by .8 to incorporate a 4:1 refuse to fill factor.

3. Savings is simply the tons recovered multiplied by the landfill space multiplier.

4. Tonnage of source reduced material comes from Table A-1.

5. Landfill space multipliers are calculated using the landfill density of each material from Table B-9 of the EPA's *Characterization of MSW in US: 1997 Update*. The density was converted to the units of cubic feet per ton and divided by .8 to incorporate a 4:1 refuse to fill factor.

6. Savings is simply the tons source reduced multiplied by landfill space factor.

7. Total savings is the sum of the savings from recovery and source reduction.

Table A-4: Forest Acreage Saved due to Iowa Source Reduction, 1995

	Tons Source Reduced[1]	Tons of Trees Required per ton of Virgin Material[2]	Virgin Inputs in Current Mix[3]	Total Trees Saved (tons)[4]	Tons of Trees per Acre[5]	Total Acres Saved by Source Reduction[6]
Paper	**49,533**			**49,584**		**12,396**
Newspaper	31,952	1.79	56%	31,961	4	7,990
OCC and Kraft Bags	NA	3.27	54%	NA	4	NA
High Grade	NA	3.65	69%	NA	4	NA
Other	17,581	1.79	56%	17,623	4	4,406

Notes to Table A-4

1. Tonnage of source reduced material comes from Table A-1.

2. Ton of trees required per ton of virgin material is the amount of trees needed to make one ton of paper. These figures were calculated by Tellus using data from *Energy Implications of Integrated Solid Waste Management Systems*, a publication of the New York State Energy Research and Development Authority. Because no data was available for Other Paper, the newspaper value was used as a proxy.

3. Virgin inputs in current mix is the percentage of virgin inputs (i.e. from trees, not from recycled paper) that is used to make new paper. This figure comes from exhibit 2-2 of the EPA report *Greenhouse Gas Emissions from Selected Materials in Municipal Solid Waste*. Because no data was available for other paper, the newspaper value was used as a proxy.

4. Total Trees Saved = Tons Source Reduced × Tons of Trees Required per Ton of Virgin Material × Virgin Inputs in Current Mix.

5. Tons of trees per acre is the sustainable yield of a southern pine forest per Al Gertsel, American Forests and Paper Association, personal communication Nov. 7, 1996.

6. Total Acres = Total Trees Saved ÷ Trees per Acre

Table A-5: Forest Acreage Saved due to Iowa Recycling, 1995

	Tons Recycled[1]	Tons of Product Made Per Ton of Recovered Materials[2]	Tons of Trees Required Per Ton of Virgin Material[3]	Total Trees Saved (tons)[4]	Tons of Trees per Acres[5]	Total Acres Saved by Recycling[6]
Paper	**367,175**			**794,405**		**198,601**
Newspaper	88,294	0.77	1.79	121,439	4	30,360
OCC and Kraft Bags	225,047	0.77	3.27	566,032	4	141,508
High Grade	31,699	0.66	3.65	76,426	4	19,106
Other	22,135	0.77	1.79	30,509	4	7,627

Notes to Table A-5

1. Tonnage of recycled material comes from Table A-1.

2. The ton of product made per ton of recovered material is the amount of new paper, which can be made from a ton of recycled paper. This data comes from Exhibit 4-3 of the EPA report *Greenhouse Gas Emissions from Selected Materials in Municipal Solid Waste.*

3. Ton of trees required per ton of virgin material is the tons of trees need to make one ton of paper. These figures were calculated by Tellus using data from *Energy Implications of Integrated Solid Waste Management Systems*, a publication of the New York State Energy Research and Development Authority. Because no data was available for other paper, the newspaper value was used as a proxy.

4. Total Trees Saved = Tons Recycled × Ton of Product Made Per Ton of Recovered Material × Tons of Trees Required per Ton of Virgin Material

5. Tons of trees per acre is the sustainable yield of a southern pine forest per Al Gertsel, American Forests and Paper Association, personal communication Nov. 7, 1996.

6. Total Acres = Total Trees Saved ÷ Trees per Acre

Table A-6: Energy Benefits from Iowa Diversion, 1995

	Recovery			Source Reduction			Total
	Tons[1]	Million BTU/ton[2]	Savings (Million BTU)[3]	Tons[4]	Million BTU/ton[5]	Savings (Million BTU)[6]	Savings (Million BTU)[7]
Paper	**367,175**		**5,101,675**	**49,533**		**955,371**	**6,057,047**
Newspaper	88,294	10.97	968,166	31,952	29.90	955,371	1,923,537
OCC and Kraft Bags	225,047	14.26	3,208,453	NA	24.88	NA	NA
High Grade	31,699	29.18	925,056	NA	48.21	NA	NA
Other	22,135	NA	NA	17,581	NA	NA	NA
Plastics	**23,423**		**508,877**	**(2,814)**	**35.65**	**(119,016)**	**389,861**
PET Containers	10,307	30.17	310,982	(2,291)	45.64	(104,546)	206,436
HDPE	6,286	17.44	109,597	(523)	27.67	(14,470)	95,127
LDPE	3,442	25.65	88,298	NA	38.82	NA	NA
Other	3,388	NA	NA	NA	NA	NA	NA
Glass	**28,908**	**2.49**	**72,097**	**25,829**	**6.58**	**169,969**	**242,066**
Metals	**141,321**		**3,447,202**	**27,692**		**957,827**	**4,405,029**
Steel Cans	29,036	20.37	591,566	2,525	27.02	68,226	659,791
Aluminum Cans	3,996	190.59	761,606	1,970	133.47	262,937	1,024,542
Ferrous	102,782	20.37	2,094,031	23,197	27.02	626,664	2,720,695
Non-ferrous	5,507	NA	NA	NA	NA	NA	NA
Yard Waste	**113,858**	**NA**	**NA**	**277,858**	**NA**	**NA**	**NA**
Food Waste	**NA**	**NA**	**NA**	**18,503**	**NA**	**NA**	**NA**
Wood	**39,173**	**NA**	**NA**	**30,334**	**NA**	**NA**	**NA**
Other	**166,428**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Total	**880,286**		**9,129,852**	**426,935**		**1,964,151**	**11,094,003**

Notes to Table A-6

1. Tonnage of recycled material comes from Table A-1.

2. Using data from exhibits 2-3 through 2-6 of the EPA report, *Greenhouse Gas Emissions from Selected Materials in Municipal Solid Waste* (GHG report), the per ton energy savings due to recycling was calculated for each material. The GHG report contains the energy requirements for manufacturing and transportation of products made from virgin and recycled materials. The difference between the energy requirement of products made from virgin materials and products made from recycled materials is the energy savings from recycling.

3. The energy savings is simply the tons recycled multiplied by the per ton energy savings from recycling.

4. Tonnage of source reduced material comes from Table A-1.

5. The energy savings from source reduction is the energy saved by not producing and transporting a product with the current mix of recycled and virgin inputs. Again using data from exhibits 2-3 through 2-6 of the GHG report and in addition the recycled input information from exhibit 2-2, the per ton energy savings was calculated for source reduction.

6. The energy savings is simply the tons source reduced multiplied by the per ton energy savings from source reduction.

7. Total Savings = Savings from Recycling + Savings from Source Reduction

Table A-7: Emissions Saving from Recycling in Iowa, 1995

	Emission Factor (lbs./ton)[1]	Emissions (tons)[2]
Atmospheric Emissions		
Aldehydes	0.513	114.41
Ammonia	0.008	1.69
Carbon Dioxide	2,494.200	555,842.45
Carbon Monoxide	25.200	5,615.92
Chlorine	0.045	10.07
Hydrocarbons	6.800	1,515.41
Hydrogen Fluoride	0.177	39.36
Lead	0.006	1.38
Methane	0.010	2.23
Nitrogen oxides	9.400	2,094.83
Other organics	0.273	60.84
Particulates	11.300	2,518.25
Sulfur oxides	10.900	2,429.11
Solid Wastes	831.800	185,369.96
Waterborne Waste		
Acid	0.442	98.41
Ammonia	0.094	21.04
BOD	0.538	119.81
COD	1.486	331.12
Cyanide	0.004	0.85
Dissolved solids	5.400	1,203.41
Fluorides	0.104	23.18
Iron	0.078	17.34
Metal ion	0.205	45.77
Oil	0.044	9.72
Phenol	0.002	0.53
Sulfuric Acid	0.001	0.31
Suspended solids	2.500	557.14

Notes to Table A-7

1. The emission factors come directly from page I-49 of *The Role of Recycling in Integrated Solid Waste Management to the Year 2000*, prepared for Keep America Beautiful, Inc. by Franklin Associates, Ltd,. September 1994. These factors are intended to be applied to a lump sum of recyclables with a composition of 50% paper, 32% glass, 8% steel cans, 4% aluminum, 4% HDPE, and 2% PET.

2. The emission factors are applied to the sum of paper, glass, steel cans, aluminum cans, HDPE and PET recycled in Iowa (445,708 tons) to yield the emission savings from recycling. The composition of recyclables is not the same as the composition used by Franklin/Keep America Beautiful. However, as shown in Table A-8, the difference in composition is such that the use of the Franklin data likely understates Iowa's emissions savings.

Table A-8: Composition of Recyclables for Air and Water Emission Calculations

	Keep America Beautiful[1]	State of Iowa[2]
Paper	50%	82%
Glass	32%	6%
Steel Cans	8%	7%
Aluminum Cans	4%	1%
HDPE	4%	1%
PET	2%	2%

Notes to Table A-8

1. The Keep America Beautiful composition is the composition of recyclables for which the emission factors in Table A-7 were intended.

2. The State of Iowa composition is the composition of recyclables to which the emissions factors were applied in Table A-7. While this composition is obviously different than the Keep America Beautiful (KAB) composition, the difference in composition will only make the emissions savings in Table A-7, a more conservative estimate. This is because the main difference between the KAB and Iowa compositions is that the Iowa composition has a larger percentage of paper and less glass than the KAB composition Glass production and disposal causes less environmental problems than paper making and disposal. Recycling proportionally more paper and less glass saves Iowa more emissions than would the KAB composition.

Table A-9: Emissions Savings Due to Source Reduction in Iowa, 1995

	CO[1]	NOX[2]	VOC[3]	SOX[4]	PM-10[5]
	Savings (Tons)	**Savings (Tons)**	**Savings (Tons)**	**Savings (Tons)**	**Savings (Tons)**
Paper	**91.78**	**322.92**	**10.64**	**470.14**	**30.22**
Newspaper	91.78	322.92	10.64	470.14	30.22
OCC and Kraft Bags	NA	NA	NA	NA	NA
High Grade	NA	NA	NA	NA	NA
Other	-	-	-	-	-
Plastics	**(12.73)**	**(26.80)**	**(1.42)**	**(36.14)**	**(4.87)**
PET Containers	(11.41)	(23.73)	(1.26)	(32.03)	(4.38)
HDPE	(1.32)	(3.07)	(0.16)	(4.11)	(0.49)
LDPE	NA	NA	NA	NA	NA
Other	NA	NA	NA	NA	NA
Glass	**24.28**	**29.62**	**3.11**	**28.04**	**9.72**
Metals	**183.98**	**220.12**	**20.43**	**246.61**	**76.26**
Steel Cans	16.55	15.38	1.86	14.59	7.00
Aluminum Cans	15.42	63.51	1.51	97.99	4.97
Ferrous	152.01	141.23	17.06	134.03	64.29
Non-ferrous	NA	NA	NA	NA	NA
Yard Waste	**-**	**-**	**-**	**-**	**-**
Food Waste	**-**	**-**	**-**	**-**	**-**
Wood	**-**	**-**	**-**	**-**	**-**
Other	**NA**	**NA**	**NA**	**NA**	**NA**
Total	**287**	**546**	**33**	**709**	**111**

Notes to Table A-9

1. The carbon monoxide emissions saving from source reduction were calculated by splitting the energy savings from Table A-6 into process, transportation and electric energy using data from exhibits 2-3 to 2-6 of the GHG report. Then using multipliers for carbon monoxide emissions saved per MMBtu of process, transport and electric energy, the carbon monoxide emissions savings was calculated. The emission factors are shown in the table below. The emission factors for are calculated by taking the total carbon dioxide emitted by the transportation, process or electric sector per the EPA's *National Air Pollutant Emissions Trends, 1900-1996* and dividing by the total energy use in the transportation, process or electric sectors per the U.S. Energy Information Administration's *Annual Energy Outlook 1997*.

Emission Factors (lb/MMBTU)

Type of Energy	CO	NOx	VOC	SOX	PM-10
Transportation	2.64	0.91	0.28	0.03	0.08
Process	0.09	0.28	0.02	0.29	0.03
Electricity	0.034	0.529	0.004	0.905	0.025

2. Same as for Carbon Monoxide but with different multipliers. The emission factors are shown in the table above.

3. Same as for Carbon Monoxide but with different multipliers. The emission factors are shown in the table above.

4. Same as for Carbon Monoxide but with different multipliers. The emission factors are shown in the table above.

5. Same as for Carbon Monoxide but with different multipliers. The emission factors are shown in the table above.

Table A-10: Greenhouse Gas Emissions Savings from Iowa Waste Diversion, 1995

Material	Recovery			Source Reduction			Total	
	Diverted[1]	Emission Factor[2]	Avoided GHGs[3]	Diverted[4]	Emission Factor[5]	Avoided GHGs[6]	Diverted[7]	Avoided GHGs[8]
	Tons	MTCE/Ton	MTCE	Tons	MTCE/Ton	MTCE	Tons	MTCE
Paper	**367,175**		**274,289**	**49,533**		**45,075**	**416,708**	**319,364**
Newspaper	88,294	0.86	75,933	31,952	0.91	29,076	120,246	105,009
OCC and Kraft Bags	225,047	0.7	157,533	NA	0.78	NA	225,047	157,533
High Grade	31,699	0.82	25,993	NA	1.03	NA	31,699	25,993
Other	22,135	0.67	14,830	17,581	0.91	15,999	39,716	30,829
Plastics	**23,423**		**12,167**	**(2,814)**	0.85	**(2,387)**	**20,609**	**9,780**
PET	10,307	0.62	6,390	(2,291)	0.98	(2,245)	8,016	4,145
HDPE	6,286	0.37	2,326	(523)	0.61	(319)	5,763	2,007
LDPE	3,442	0.49	1,687	NA	0.89	NA	3,442	1,687
Other	3,388	0.52	1,765	NA	NA	NA	3,388	1,765
Glass	**28,908**	**0.08**	**2,312.64**	**25,829**	**0.14**	**3,616**	**54,737**	**5,929**
Metals	**141,321**		**90,641**	**27,692**		**27,477**	**169,013**	**118,118**
Steel Cans	29,036	0.57	16,551	2,525	0.84	2,121	31,561	18,672
Aluminum Cans	3,996	3.88	15,504	1,970	2.98	5,870	5,966	21,375
Ferrous	102,782	0.57	58,586	23,197	0.84	19,485	125,979	78,071
Non-ferrous	5,507	NA	NA	NA	NA	NA	5,507	NA
Yard Waste	**113,858**	**NA**	**NA**	**277,858**	**NA**	**NA**	**391,716**	**NA**
Food Waste	**NA**	**NA**	**NA**	**18,503**	**NA**	**NA**	**18,503**	**NA**
Wood	**39,173**	**NA**	**NA**	**30,334**	**NA**	**NA**	**69,507**	**NA**
Other	**159,764**	**NA**	**NA**	**NA**	**NA**	**NA**	**166,428**	**NA**
Total	**873,622**		**379,410**	**426,935**		**73,780**	**1,307,220**	**453,190**

Notes to Table A-10

1. Tonnage of recovered material comes from Table A-1.

2. GHG multipliers come from Exhibit 8-5 of EPA report, *Greenhouse Gas Emissions from Selected Materials in Municipal Solid Waste.*

3. The avoided GHGs are simply the tons recycled multiplied by the per ton GHG savings from recycling.

4. Tonnage of source reduced material comes from Table A-1.

5. GHG multipliers come from Exhibit 8-5 of EPA report, *Greenhouse Gas Emissions from Selected Materials in Municipal Solid Waste.*

6. The avoided GHGs are simply the tons source reduced multiplied by the per ton GHG savings from source reduction.

7. Total Diversion = Tons Recovered + Tons Source Reduced

8. Total Avoided GHGs = avoided GHGs from Recycling + avoided GHGs from Source Reduction

Table A - 11: Disposal and Diversion Tonnage Data for Fifty Percent Diversion Scenario

	Source Reduction[1]		Recovery[2]		Disposal[3]		Diversion[4]		Generation[5]		Diversion Rate[6]
	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent
Paper	**17.0%**	**94,707**	**35.2%**	**489,692**	**25.7%**	**500,595**	**30.0%**	**584,399**	**27.8%**	**1,084,994**	**53.9%**
Newspaper	6.7%	37,133	7.4%	102,612	3.0%	58,209	7.2%	139,745	5.1%	197,953	70.6%
OCC and Kraft Bags	0.0%	-	19.5%	271,195	7.1%	137,761	13.9%	271,195	10.5%	408,955	66.3%
High Grade	0.0%	-	3.1%	43,398	1.8%	34,925	2.2%	43,398	2.0%	78,324	55.4%
Other	10.4%	57,574	5.2%	72,487	13.8%	269,700	6.7%	130,062	10.3%	399,762	32.5%
Plastics	**-0.7%**	**(3,784)**	**7.0%**	**98,164**	**11.3%**	**220,223**	**4.8%**	**94,381**	**8.1%**	**314,603**	**30.0%**
PET Containers	-0.5%	(2,848)	0.9%	12,814	0.3%	5,821	0.5%	9,966	0.4%	15,787	63.1%
HDPE	-0.2%	(936)	0.8%	11,249	0.7%	13,582	0.5%	10,313	0.6%	23,895	43.2%
LDPE	0.0%	-	0.2%	3,442	0.0%	-	0.2%	3,442	0.1%	3,442	NA
Other	0.0%	-	5.1%	70,660	10.3%	200,820	3.6%	70,660	7.0%	271,480	26.0%
Glass	**5.6%**	**31,043**	**2.5%**	**34,743**	**1.7%**	**32,985**	**3.4%**	**65,787**	**2.5%**	**98,772**	**66.6%**
Metals	**5.9%**	**32,786**	**12.1%**	**168,401**	**4.9%**	**96,044**	**10.3%**	**201,186**	**7.6%**	**297,231**	**67.7%**
Steel Cans	0.5%	2,942	2.4%	33,820	0.8%	15,522	1.9%	36,761	1.3%	52,283	70.3%
Aluminum Cans	0.4%	2,399	0.3%	4,867	0.2%	3,881	0.4%	7,266	0.3%	11,146	65.2%
Ferrous	4.9%	27,445	8.7%	121,607	3.5%	68,880	7.6%	149,052	5.6%	217,933	68.4%
Non-ferrous	0.0%	-	0.6%	8,107	0.4%	7,761	0.4%	8,107	0.4%	15,868	51.1%
Yard Waste	**50.0%**	**277,858**	**8.2%**	**113,858**	**1.7%**	**33,673**	**20.1%**	**391,716**	**10.9%**	**425,389**	**92.1%**
Food Waste	**12.0%**	**66,600**	**NA**	**-**	**NA**	**143,581**	**3.4%**	**66,600**	**5.4%**	**210,182**	**31.7%**
Wood	**10.2%**	**56,998**	**5.3%**	**73,606**	**9.4%**	**182,387**	**6.7%**	**130,604**	**8.0%**	**312,992**	**41.7%**
Other	**0.0%**	**-**	**29.7%**	**414,066**	**37.9%**	**739,250**	**21.2%**	**414,066**	**29.6%**	**1,153,316**	**35.9%**
Total	**100%**	**556,208**	**100%**	**1,392,531**	**100%**	**1,948,739**	**100%**	**1,948,739**	**100%**	**3,897,478**	**50.0%**

Notes to Table A-13

1. Yard waste diversion was assumed to remain constant between the current 33.5% diversion scenario and the 50% diversion scenario. The additional diversion over the current scenario was calculated by determining the fraction of the disposed tons in the current scenario that should be diverted in the 50% diversion scenario. This fraction was determined using the following equation:

$$\frac{(33.5\%\ \text{Disposal} - 50\%\ \text{Disposal})}{(33.5\%\ \text{Disposal} - \text{Yard Waste Disposal})}$$

   The 33.5% disposal for each material type was multiplied by this fraction to determine the additional diversion for each material type. The additional diversion is spread between source reduction and recycling using the ratio of source reduction to recycling in the current 33.5% diversion scenario. The total source reduction in the 50% diversion scenario is the source reduction in the 33.5% diversion scenario plus the additional source reduction as calculated.

2. Yard waste diversion was assumed to remain constant between the current 33.5% diversion scenario and the 50% diversion scenario. The additional diversion over the current scenario was calculated by determining the fraction of the disposed tons in the current scenario that should be diverted in the 50% diversion scenario. This fraction was determined using the following equation:

$$\frac{(33.5\%\ \text{Disposal} - 50\%\ \text{Disposal})}{(33.5\%\ \text{Disposal} - \text{Yard Waste Disposal})}$$

The 33.5% disposal for each material type was multiplied by this fraction to determine the additional diversion for each material type. The additional diversion is spread between source reduction and recycling using the ratio of source reduction to recycling in the current 33.5% diversion scenario. The total recycling in the 50% diversion scenario is the recycling in the 33.5% diversion scenario plus the additional recycling as calculated.

3. Disposal is the generation from Table A-1 minus the 50% scenario diversion.

4. Diversion is source reduction plus recovery.

5. Generation is source reduction plus recovery plus disposal.

6. Diversion rate equals diversion divided by generation.